

SEMICONDUCTOR CHIP HAVING BOND PADS AND MULTI-CHIP PACKAGE

This application is a divisional of U.S. Patent Application No. 10/192,800, filed on July 9, 2002, now pending, which is herein incorporated by reference in its entirety.

5

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to semiconductor devices and, more particularly, to a semiconductor chip having bond pads and to a multi-chip package (MCP).

10

2. Description of the Related Art

The industry is expending significant effort toward forming smaller and thinner chips to meet the demand for high packing density in high-speed, multi-functional semiconductor devices. To reduce chip size, the size of bond pads as well as the pitch between bond pads should be reduced.

15

Conventional semiconductor chips have either a center pad-type or a peripheral pad-type structure. FIG. 1 is a plan view of a conventional center pad-type semiconductor chip. FIG. 2 is a cross-sectional view of the conventional center pad-type chip taken along line 2-2 of FIG. 1. FIG. 3 is a plan view of a conventional peripheral pad-type semiconductor chip. FIG. 4 is a cross-sectional view of the conventional peripheral pad-type chip taken along the line 4-4 of FIG. 3.

20

Referring to FIGS. 1 and 2, a center pad-type semiconductor chip 110 comprises a peripheral circuit region A_{peri} for forming bond pads 112 and cell regions A_{cell1} and A_{cell2} . The peripheral circuit region A_{peri} is formed in the center region of a semiconductor substrate 111. The cell regions A_{cell1} and A_{cell2} are formed on the sides of the peripheral circuit region A_{peri} .

25

30

Referring to FIGS. 3 and 4, a peripheral pad-type semiconductor chip 120 comprises peripheral circuit regions A_{peri1} and A_{peri2} , and a cell region A_{cell} . The cell region A_{cell} is formed in the center region of the semiconductor substrate 121. The peripheral circuit regions A_{peri1} and A_{peri2} are formed on the sides of the cell region A_{cell} . Referring to FIGS. 2

and 4, a passivation layer 113, 123 is formed over the cell regions and the peripheral circuit regions in both the center and peripheral pad-type chips.

In the conventional semiconductor chips 110, 120 of FIGS. 1 through 4, an additional chip area is needed in peripheral circuit regions for forming bond pads 112, 122. As a result, the ability to reduce the size of the conventional semiconductor chips 110 and 120 is limited in both chip pad types.

Furthermore, it has been difficult to reduce the bond pad size and the pitch between the bond pads 112, 122 in the conventional semiconductor chips 110 and 120. This is because the bond pads 112, 122 must have a designed minimum size and pitch for electric die sorting (EDS) and to form electrical interconnections.

The ability to reduce the size of a multi-chip package (MCP) including multiple conventional semiconductor chips in a single body package is also limited due to problems such as the difficulty of stacking center pad-type chips on chips of the same or similar types. That is, wire bonding can be complicated and difficult due to long loop wires in such cases.

Accordingly, there is a need for a smaller semiconductor chip that can easily form an MCP without suffering from the problems mentioned above.

SUMMARY OF THE INVENTION

A semiconductor chip comprises a semiconductor substrate having integrated circuits formed on a cell region and a peripheral circuit region adjacent to each other. A bond pad-wiring pattern is formed on the semiconductor substrate. A pad-rearrangement pattern is electrically connected to the bond pad-wiring pattern. The pad-rearrangement pattern includes a bond pad disposed over at least a part of the cell region. According to one embodiment, the bond pad-wiring pattern is formed substantially in a center region of the semiconductor substrate. According to another embodiment, a portion of the pad-rearrangement pattern extends substantially from the center region of the semiconductor substrate toward an edge of the semiconductor substrate. According to yet another embodiment, the bond pad-wiring pattern is formed on a portion of the peripheral circuit region and extends across a portion of the cell region.

Thus, with the embodiments of the present invention, the overall chip size can thereby be substantially reduced and an MCP can be fabricated without the problems mentioned above, thus reducing manufacturing costs and increasing productivity.

BRIEF DESCRIPTION OF THE DRAWINGS

5

The foregoing and other objects, features and advantages of the present invention will be more readily understood through the following detailed description provided with reference to the accompanying figures, wherein like reference numerals designate like structural elements, and, in which:

10 FIG. 1 is a plan view of a conventional center pad-type semiconductor chip;

FIG. 2 is a cross-sectional view of the conventional center pad-type taken along the line 2-2 of FIG. 1;

FIG. 3 is a plan view of a conventional peripheral pad-type semiconductor chip;

15 FIG. 4 is a cross-sectional view of the peripheral pad-type chip taken along the line 4-4 of FIG. 3;

FIGS. 5 to 8 are cross-sectional views of a semiconductor chip illustrating a process of manufacturing a semiconductor chip according to an embodiment of the present invention;

FIG. 9 is a plan view of the semiconductor chip shown in FIG. 8;

20 FIG. 10 is an enlarged cross-sectional view of a semiconductor chip illustrating an alternative configuration of portion A of FIG. 8;

FIG. 11 is a cross-sectional view of the semiconductor chip of FIG. 9, following wire bonding;

FIG. 12 is a cross-sectional view illustrating a semiconductor chip according to another embodiment of the present invention;

25 FIGS. 13 to 15 are cross-sectional views of a semiconductor chip illustrating a process of manufacturing a semiconductor chip according to yet another embodiment of the present invention;

FIG. 16 is a cross-sectional view of a semiconductor chip according to a further embodiment of the present invention;

30 FIG. 17 is a cross-sectional view of a semiconductor chip according to a still further embodiment of the present invention;

FIG. 18 is a cross-sectional view of an MCP according to another embodiment of the present invention;

FIG. 19 is a cross-sectional view of an MCP according to another embodiment of the present invention;

FIG. 20 is a cross-sectional view of an MCP according to yet another embodiment of the present invention;

5 FIG. 21 is a cross-sectional view of an MCP according to a further embodiment of the present invention;

FIG. 22 is a cross-sectional view of an MCP according to a still further embodiment of the present invention; and

10 FIG. 23 is a cross-sectional view of an MCP according to a still further embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

15 Fig. 8 is a cross-sectional view of a semiconductor clip 10 constructed according to an embodiment of the present invention. Referring to FIG. 8, a semiconductor chip 10 comprises a semiconductor substrate 11 having integrated circuits formed thereon. In particular, the semiconductor substrate 11 includes a peripheral circuit region A_{peri} formed in the center region thereof and cell regions A_{cell1} and A_{cell2} arranged on the sides of the peripheral circuit region A_{peri} . A bond pad-wiring pattern 12 is formed in a predetermined area of the substrate 11. The bond pad-wiring pattern 12 can be made of a metal having excellent electrical conductivity, such as aluminum (Al).

25 The bond pad-wiring pattern 12 is preferably formed in a center region of the semiconductor substrate 11. One end of the bond pad-wiring pattern 12 is preferably formed on the portion of the peripheral circuit region A_{peri} . In the conventional semiconductor chip, an additional chip area is needed in peripheral circuit regions for forming bond pads having a minimum size and pitch designed for electric die sorting (EDS) and making electrical interconnections. According to the forgoing embodiment of the present invention, however, no larger additional area for forming bond pads is required, rather only the small portion of the bond pad-wiring pattern 12 needs to be formed on the peripheral circuit region A_{peri} . The remaining portion of the bond pad-wiring pattern 12 extends across a portion of the cell region according to an embodiment of the present invention. The width of the semiconductor substrate 11 can therefore be reduced by approximately the width of the bond pad area of the conventional semiconductor chip.

According to another aspect of the present invention, as shown in Fig 16, the bond pad-wiring pattern 12 can alternatively be formed entirely within the peripheral circuit region. Also, the bond pad-wiring pattern 12 can be formed entirely within the cell region (although not shown). In these cases, the size of the bond pad-wiring pattern 12 can be made small because a designed minimum size and pitch for electric die sorting (EDS) and electrical interconnections is not needed.

Thus, with the embodiments of the present invention, the overall chip size can thereby be substantially reduced using the above-described principles of the present invention as explained above and further below.

A passivation layer 16 is formed on the bond pad-wiring pattern 12. An interlayer dielectric (ILD) 13 is then formed on the passivation layer 16. The ILD 13 is made of a material having good insulation and integration properties to protect bond pads 17 from mechanical stress due to subsequent wire bonding, beam lead bonding, or ball bonding. For example, a high-density plasma (HDP) oxidized layer, a benzocyclobutene (BCB) layer, a polybenzoxazole (PBO) layer, or a polyimide layer may be used as the ILD 13. An HDP oxide layer using silan, oxygen and argon gases, for example, an HDP-SiO₂ layer is preferably used. The passivation layer 16 and the ILD 13 have openings 14 formed therein to expose predetermined portions of the bond pad-wiring pattern 12a.

A pad-rearrangement pattern 15, having a predetermined layout, is formed on the ILD 13. As shown in portion "A" of FIG. 8, the openings 14 are filled with the pad-rearrangement pattern 15. An alternative configuration of portion A of FIG. 8 is illustrated in FIG. 10. The pad-rearrangement pattern 15 preferably comprises three layers. These three layers can, for example, include a titanium (Ti) layer having a thickness of about 300 to 500Å, an aluminum (Al) layer having a thickness of about 15,000Å, and a titanium nitride (TiN) layer having a thickness of about 300 to 500Å. The pad-rearrangement pattern 15 may be formed of copper (Cu), aluminum (Al), zinc (Zn), iron (Fe), platinum (Pt), cobalt (Co), lead (Pb), nickel (Ni), or an alloy of these elements.

An insulating layer 18 is formed on the pad-rearrangement pattern 15. The insulating layer 18 may be an HDP oxide layer such as an HDP-SiO₂ layer or an HDP-SiN layer. The

insulating layer 18 may further comprise a polyimide layer on the HDP-SiO₂ layer so as to protect integrated circuits from alpha particles. A predetermined portion of the pad-rearrangement pattern 15 is exposed through the insulating layer to define the bond pads 17. The bond pads 17 are preferably flush with the pad-rearrangement pattern 15. The bond pads 17 are disposed above at least part of the cell regions A_{cell1}, A_{cell2} of the substrate 11. Although the bond pads 17 shown in FIG. 9 are disposed in a single row along opposing edges of the substrate 11, the pads 17 may be disposed along all four edges or in a zigzag shape.

According to one embodiment, the pad-rearrangement pattern 15 reroutes the bond pads 17 from the bond pad-wiring pattern 12 in the peripheral circuit region A_{peri} to above the cell regions A_{cell1} and A_{cell2}. As shown above, one end of the pad-rearrangement pattern 15 is electrically connected to the exposed bond pad-wiring pattern 12 via openings 14. The other end extends toward the edge of the substrate 11. In other words, according to one aspect of the present invention, the portion of the pad-rearrangement pattern 12 extends substantially from the center region of the semiconductor substrate 11 toward an edge of the semiconductor substrate 11. The bond pads 17 can therefore be formed along sides of the semiconductor substrate 11. Thus, according to various embodiments of the present invention, peripheral pad type semiconductor chips can be fabricated using center pad type semiconductor chips, which are known to have improved electrical performance characteristics over the peripheral pad type chips. The pitch between the bond pads can increase. During the EDS test, a probe can easily contact the bond pads. These modified peripheral pad chips thus need not be packaged in a lead-on-chip (LOC) type package, but may be implemented in a conventional package.

Referring to FIG. 11, electrical connection means such as bonding wires 99 are coupled to the bond pads 17. If necessary, the positions of bond pads 17 can be adjusted depending on the design and structure of the electrical interconnections.

As described above, the bond pads 17 of this embodiment are preferably formed over at least a part of the cell regions of the substrate 11. Therefore, the peripheral circuit region A_{peri} has a much smaller width than that of the conventional peripheral circuit region. Thus, the total width of the semiconductor chip 10 can be reduced. The widths of the cell regions A_{cell1}¹ and A_{cell2} may be the same as that of the conventional cell region. Of course, the total

thickness of the semiconductor chip 10 increases due to the formation of the pad-rearrangement pattern 15 and the insulating layer 18 above the cell regions A_{cell1} or A_{cell2} . The increased percentage in total thickness of the chip 10 is no more than the reduced percentage of the total width of the chip 10. The total size of the chip 10 can be therefore reduced.

5

A method of manufacturing the above-described semiconductor chip 10 will now be described. Referring to FIG. 5, a semiconductor substrate 11 includes on-chip circuits formed on the cell regions A_{cell1} , A_{cell2} and the peripheral circuit region A_{peri} . If the semiconductor chip 10 is a memory device, the circuits formed on the cell regions A_{cell1} , A_{cell2} are memory cells having MOS transistors and capacitors, while the circuits formed on the peripheral circuit region include, for example, address decoding circuits and data input/output buffers for the memory cells. The bond pad-wiring pattern 12 is formed on the substrate 11 to be selectively connected to the integrated circuits. The passivation layer 16 is then formed on the bond pad-wiring pattern 12. The bond pad-wiring pattern 12 is formed in a predetermined layout using conventional techniques such as chemical vapor deposition (CVD) or physical vapor deposition (PVD) including sputtering. As described above, although the bond pad-wiring pattern 12 can be formed on both the cell regions A_{cell1} , A_{cell2} and the peripheral circuit region A_{peri} , the bond pad-wiring pattern may be formed just the cell regions A_{cell1} , A_{cell2} (not shown).

15
20

Next, as shown in FIG. 6, the ILD 13 is formed on the passivation layer 16. Openings 14 are formed extending through the passivation layer 16 and the ILD 13 to expose predetermined portions of the bond pad-wiring pattern 12. The ILD 13 is made of a material such as HDP-SiO₂ having good integration and insulating qualities. The integrated circuits under the ILD 13 can therefore be protected from physical stresses during the formation of electrical interconnections. The ILD 13 also helps planarize the underlying structure. The openings 14 can be formed above either the cell regions A_{cell1} , A_{cell2} or the peripheral circuit region A_{peri} .

25
30

Although the forgoing embodiment comprises a single ILD, the present invention may comprise two or more ILDs, as shown in FIG. 12 and FIG. 17. Referring to FIGS. 12 and 17, second ILDs 20a, 20 can be interposed between the ILD 13 and the pad-rearrangement pattern 15. In particular, as illustrated in FIGS. 12 and 17, because the second ILDs 20a, 20 are interposed between the ILD 13 and the pad-rearrangement pattern 15, the electrical

properties of the semiconductor chips 30, 90 are improved. The capacitance, for example, can be lowered. The thickness of the second ILD 20a is between 2 to 50 μm , for example determined base on the capacitance and the intensity supplement. The second ILD 20a may be made of benzocyclobutene (BCB), polybenzoxazole (PBO), polyimide, and so on. Also, in this case, the planarization process is preferably performed on the ILDs to improve the planarity of the ILDs 13, 20a or 20. Accordingly, the planarity of the pad-rearrangement pattern 15 thereon can be in turn improved. Further, connection failures of the bonding wires or the beam leads on the bond pads 17 are prevented and the adhesion therebetween are improved. The planarization is preferably accomplished through chemical and mechanical polishing (CMP).

According to one aspect of the present invention, the ILDs 13 and 20 of the semiconductor chip 90 (FIG. 17) distribute mechanical stresses during the formation of the electrical interconnections and protect the bond pads 17 from the mechanical stresses. In addition, since the bond pads 17 are formed after two planarization processes on the two ILDs, the bonding stability of the wire bonding between the bond pads 17 and the external device is improved.

Referring to FIG. 7, the pad-rearrangement pattern 15 is formed on the ILD 13. The pad-rearrangement pattern 15 fills the openings 14 and is electrically connected to the bond pad-wiring pattern 12. The pad-rearrangement pattern 15 is obtained in a desired layout using CVD or sputtering, for example.

Referring to FIG. 8, an insulating layer 18 is formed on the pad-rearrangement pattern 15 and includes an opening 19 to expose predetermined portions of the pad-rearrangement pattern 15. The exposed portions of the pattern 15 are defined as the bond pads 17. The insulating layer 18 is preferably made of HDP-SiO₂ to protect the integrated circuits from mechanical stresses. The insulating layer 18 may further comprise a polyimide layer on the HDP-SiO₂ layer to protect the integrated circuits from alpha particles. The ILD 20a and the insulating layer 18 can alternatively made of polyimide.

FIGS. 13 through 15 are cross-sectional views of a semiconductor chip illustrating a process of manufacturing a semiconductor chip in accordance with another embodiment of the present invention. In this embodiment, as shown in FIG. 15, a semiconductor chip 50

comprises a second ILD 20b on a first ILD 13. Bond pads 17 of this embodiment, however, are formed on the first ILD 13. In order to prevent a cushioning effect due to the mechanical stress of the electrical interconnections, portions of the second ILD 20b under the bond pads 17 are removed.

5

In particular, Referring to FIGS. 13 through 15, a semiconductor substrate 11 includes a bond pad-wiring pattern 12 preferably formed on at least a portion of the peripheral circuit region A_{peri} and electrically connected thereto. A passivation layer 16 is formed on the semiconductor substrate 11 and on the bond pad-wiring pattern 12. The first ILD 13 is
10 formed over the semiconductor substrate 11 including the bond pad-wiring pattern 12. A second ILD 20b is then formed over the first ILD 13. A first opening 22 is formed through the first and second ILDs 13, 20b and the passivation layer 16 to expose a portion of the bond pad-wiring pattern 12. A second opening 24 is formed through the second ILD 20b to expose a portion of the first ILD 13. A pad-rearrangement pattern 15 is formed over the second ILD
15 20b and within the first opening 22 and is electrically connected to the bond pad-wiring pattern 12. The pad-rearrangement pattern 15 is also formed within the second opening 24. An insulating layer 18 is formed over the pad-rearrangement pattern 15 and includes an opening 26 therein that exposes a portion of the pad-rearrangement pattern 15 formed within the second opening 24 to define the bond pads 17 over at least a part of the cell region A_{cell} .
20 The portions of the pad-rearrangement pattern 15 not covered by the insulating layer 18 provide the bond pads 17. This embodiment has the similar features as described previously. For example, the bond pad-wiring pattern 12 is formed substantially in a center region of the semiconductor substrate 11.

25 Various MCPs utilizing the semiconductor chips according to the embodiments of the present invention are obtainable, which will be explained below. Referring to FIG. 18, an MCP 200 preferably comprises a first chip 210a and a second chip 210b that are vertically stacked on a package substrate 251. A printed circuit board (PCB) or tape wiring substrate can be used as the package substrate 251. The substrate surface preferably has a plurality of
30 bonding tips 253 formed thereon. The first and second chips 210a and 210b are preferably the same type of chips. The first and second chips 210a and 210b can have structures formed in accordance with the principles of the present invention described previously. For example, a bond pad-wiring pattern can be formed substantially in a center region of a semiconductor substrate, for example. Accordingly, the bond pads 217a and 217b of the first and second

chips 210a and 210b are formed over cell regions along sides of the chips 210a and 210b. Thus, the chips 210a and 210b can have a modified configuration, i.e., a center pad-type chip can be modified into a peripheral pad-typed chip.

5 The first and second chips 210a and 210b are electrically connected to the package substrate 251 by electrical connection means such as bonding wires 257, which are in turn electrically connected to the bonding tips 253. Thus, each bonding tip 253 is electrically connected to a corresponding one of the bond pads 271a, 271b.

10 The first chip 210a is mounted on the package substrate 251 with an adhesive 261, and the second chip 210b is mounted on the first chip 210a with an adhesive material 263. The adhesive material 263 is interposed between the first and second chips 210a and 210b, thus ensuring enough space for the bonding wires 257 used in connecting the first chip 210a with the package substrate 251.

15 An encapsulant 259, formed of a material such as an epoxy molding compound, protects the upper surface of the package substrate 251 from an external environment by encapsulating the first and second chips 210a, 210b and the bonding wires 257. Solder balls 271 are formed on the lower surface of the package substrate 251 to provide external
20 connection terminals.

 As described above, since the MCP 200 according to this embodiment includes multiple semiconductor chips in a single package body, the principles of the present invention can be used to increase memory capacity as well as the number of input/output pins without
25 complicated assembly processes.

 Referring to FIG. 19, an MCP 300 according to another embodiment of the present invention comprises a first chip 310a and a second chip 310b mounted side by side on a package substrate 351. Here, the first and second chips 310a, 310b preferably have structures
30 the same as or similar to the structures described in FIG. 21 or the same as or similar to structures of the chip embodiments described above. For example, the first and second chips 310a, 310b are preferably electrically connected to the substrate 351 by bonding wires 357 through bonding tips 353. Reference numerals 359, 361, 371 are used herein to denote an encapsulant, adhesives, and solder balls, respectively.

Referring now to FIG. 20, an MCP 400 according to yet another embodiment of the present invention comprises three semiconductor chips 410a, 410b, 410c that are stacked sequentially on a package substrate 451. The chips 410a, 410b, 417c preferably have structures similar to structures described previously in accordance with the principles of the present invention. For example, the semiconductor chips 410a, 410b, 410c are preferably peripheral pad-type chips having realignment bond pads 417a, 417b, 417c formed over cell regions along a periphery (or sides) thereof. The semiconductor chips 410a, 410b, 410c can have different widths from each other. For example, the semiconductor chips 410a, 410b, 410c are preferably stacked in order of size, i.e., from the largest chip 410a to the smallest chip 410c. Different configurations are possible, however, depending on applications. For example, any two of the chips 410a, 410b, 410c may have the same width.

The semiconductor chips 410a, 410b, 410c are preferably electrically connected to the substrate 451 by bonding wires 457 through bonding tips 453. As described above, the MCP 400 of this embodiment can comprise different types of chips. Since the center pad-type chip is modified into a peripheral pad-type chip, it is possible to vertically stack the multiple chips and the lengths of the bonding wires can be made shorter to allow easier wire bonding.

Turning to FIG. 21, an MCP 500 according to yet another embodiment of this invention is a dual die package (DDP) comprising first and second semiconductor chips 510a, 510b. A lead frame 551 is used to mount the chips 510a, 510b. The second semiconductor chip 510b is preferably formed in accordance with the principles of the present invention described above. For example, the second semiconductor chip 510b can be a peripheral pad-type chip having a realignment bond pad 517b formed on the peripheral circuit region along sides of the chips 510a, 510b. In contrast, the first semiconductor chip 510a preferably has a center pad-type bond pad 517a.

The MCP 500 of this embodiment does not include die pads for mounting the semiconductor chips 510a, 510b. Instead, the leads of the lead-frame 551 employed in the LOC type package are preferably used. The length of the leads of the lead frame 551 is preferably longer than that of the conventional leads, but this is not required. The upper surface of the first semiconductor chip 510a is attached to lower surfaces of opposing leads of the lead frame 551 by adhesive tape 563. The bond pad 517a of the first chip 510a is disposed

between the opposing leads of the lead frame 551 and is wire-bonded to the upper surface of the corresponding leads of the lead frame 551 by bonding wires 557a. The upper surface of the second chip 510b is attached to the lower surface of the first chip 510a with an adhesive 561. The realignment bond pad 517b of the second chip 510b is wire-bonded to the lower surface of the corresponding leads of the lead frame 551 by bonding wires 557b. The first and second chips 510a, 510b and corresponding bonding wires 557a, 557b are encapsulated by an encapsulant 559.

In summary, the MCP 500 is a DDP comprising semiconductor chips modified from a center pad-type into a peripheral pad-type or vice versa. In addition, with the MCP 500, larger semiconductor chips can be used as compared to the other embodiments described previously.

Referring to FIG. 22, an MCP 600 according to a still further embodiment of the invention is a DDP comprising first and second semiconductor chips 610a, 610b. A die pad 653 and leads 651 are used for mounting the chips 610a, 610b. The first and second chips 610a, 610b are preferably a peripheral pad-type where bond pads 617a, 617b are formed along sides of the chips 610a, 610b. The first and second chips 610a, 610b are attached to the upper and lower surfaces, respectively, of the die pad 653 with an adhesive 661. The bond pads 617a of the first chip 610a are wire-bonded to the upper surfaces of the leads 651 by bonding wires 657a. The bond pads 617b of the second chip 610b are wire-bonded to the lower surfaces of the leads 651 by bonding wires 657b. The first and second chips 610a, 610b and bonding wires 657a, 657b are encapsulated by an encapsulant 659.

The MCP 600 of this embodiment comprises chips formed in accordance with the previously-described principles of the present invention. For example, the MCP 600 can comprise semiconductor chips modified from a center pad-type into a peripheral pad-type.

Referring to FIG. 23, an MCP 700 according to a further embodiment of the present invention includes four semiconductor chips 710a, 710b, 710c, 710d. Preferably, a width of a first chip 710a is substantially greater than a width of a second chip 710b. Also, a width of a third chip 710c is preferably substantially greater than a width of a fourth chip 710d. The width of the first chip 710a is also preferably approximately equal to the width of the third chip 710c. A person skilled in the art will appreciate, however, that the widths of the first

and third chips 710a, 710c, or the second and fourth chips 710b, 710d need not necessarily be equal, but may be made different depending on a desired application.

A lead frame 751 having a die pad 753 is used to mount the chips 710a, 710b, 710c, 710d. The non-active surface of the first chip 710a is attached to the upper surface of the die pad 753. The non-active surface of the second chip 710b is attached to a portion of the active surface of the first chip 710a. The non-active surface of the third chip 710c is attached to the lower surface of the die pad 753. The non-active surface of the fourth chip 710d is attached to a portion of the active surface of the third chip 710c. The first and second chips 710a, 710b preferably face upwardly and the third and fourth chips 710c, 710d preferably face downwardly.

The bond pads 717a, 717b of the first and second chips 710a, 710b are wire-bonded to the upper surface of the lead of the lead frame 751 through first and second bonding wires 757a, 757b, respectively. The bond pads 717c, 717d of the third and fourth chips 710c, 710d are wire-bonded to the lower surface of the lead of the lead frame 751 by third and fourth bonding wires 757c, 757d, respectively. The semiconductor chips 710a, 710b, 710c, 710d and bonding wires 757a, 757b, 757c, 757d are encapsulated with an encapsulant 753. Herein, the reference numerals 761, 762, 763, and 764 each represent an adhesive.

In various embodiments of the present invention, such as those described previously, electrical connections between the chips and the lead frame or package substrate are preferably made by wire bonding. Other techniques may be used instead, however, to form an MCP according to the present invention.

Also, a person skilled in the art will appreciate that other types of lead frames or tape can be used different from the lead frames illustrated in the accompanying figures. For example, the lead frames have inner leads bent twice and outer leads are J-leaded. In this case, the bent portion of the inner leads overlies on the active surface of one of plural chips and attached thereto by an adhesive tape or other suitable adhesives.

Although the MCPs of the various preferred embodiments of the present invention are illustrated as including between two and four semiconductor chips in a single MCP body, other numbers of chips can be incorporated in an MCP depending on the desired application.

The chips can be all the same type of chip, such as memory chips, for example. As another example, one of the chips can be a DRAM and the other can be a flash memory. Alternatively, the chips can be of different types. For example, one of the chips can be a memory chip such as a flash memory, a static random access memory (SRAM), or a dynamic random access memory (DRAM), and another chip can be a non-memory chip such as a microprocessor. The present invention can therefore be used to implement a system in a package (SIP) and thereby significantly increase packing density.

Although various preferred embodiments of the present invention have been disclosed herein for illustrative purposes, those skilled in the art will appreciate that various modifications, additions, and substitutions are possible without departing from the scope and spirit of the invention as provided in the accompanying claims.